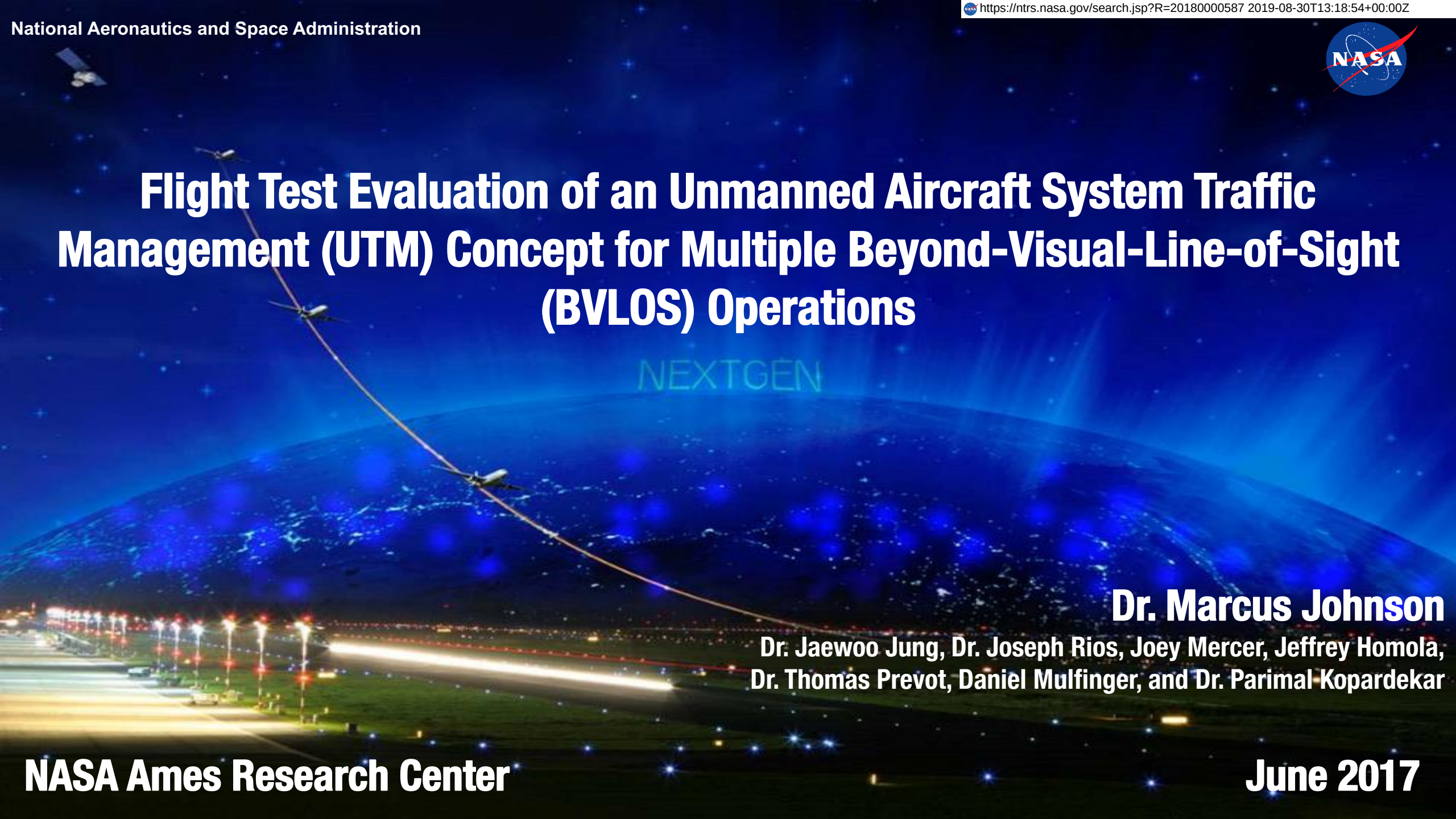
National Aeronautics and Space Administration



Flight Test Evaluation of an Unmanned Aircraft System Traffic Management (UTM) Concept for Multiple Beyond-Visual-Line-of-Sight (BVLOS) Operations

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Low Altitude UAS Operations

FAA Small UAS forecast – 7M total, 2.6M commercial by 2020

Vehicles are automated and airspace integration is necessary

New entrants desire access and flexibility for operations

Current users want to ensure safety and continued access

Regulators need a way to put safety structures in airspace

Operational concept being developed to address beyond-visual-line-of-sight (BVLOS) UAS operations at low altitude in uncontrolled airspace using UTM construct

Challenges with Expanding Operations

Visual Line of Sight
14 CFR Part 107

BVLOS

Separation

Weather

Command and Control

Awareness

Aircraft Performance

Operations over People

What is UAS Traffic Management?

UTM is an "air traffic management" ecosystem for uncontrolled airspace

UTM utilizes industry's ability to supply services under FAA's regulatory authority where these services do not exist

UTM development will ultimately identify services, roles/responsibilities, information architecture, data exchange protocols, software functions, infrastructure, and performance requirements to enable the management of low-altitude uncontrolled UAS operations

UTM addresses critical gaps associated with lack of support for UAS operations in uncontrolled airspace

UTM Principles and Services

Principles

- Only authenticated UAS operations allowed
- UAS stay clear of each other
- UAS and manned aircraft stay clear of each other
- UAS operator has awareness of airspace and other constraints
- Public safety UAS have priority over other UAS

Key UAS-related services

- Authorization/Authentication
- Airspace configuration and static and dynamic geo-fence definitions
- Track and locate
- Communications and control (spectrum)
- Weather and wind prediction and sensing
- Conflict avoidance (e.g., airspace notification)
- Demand/capacity management
- Large-scale contingency management (e.g., GPS or cell outage)

National Airspace System- ATM

Flight Information Management System (FIMS)

Supplemental Data Service Provider(s)

UAS Service Supplier(s) (USS)

Airspace Displays

Technical Capability Level (TCL) Progression

TCL1: *multiple VLOS*

→ Networked Operations

→ Info sharing

TCL2: *multiple BVLOS, rural*

→ Initial BVLOS

→ Intent sharing

→ Separation by geo-fencing

TCL3: *multiple BVLOS, near airports, suburban*

→ Routine BVLOS

→ Detect and Avoid (DAA) / Vehicle to Vehicle (V2V)

→ Avoid static obstacles

TCL4: *complex urban BVLOS*

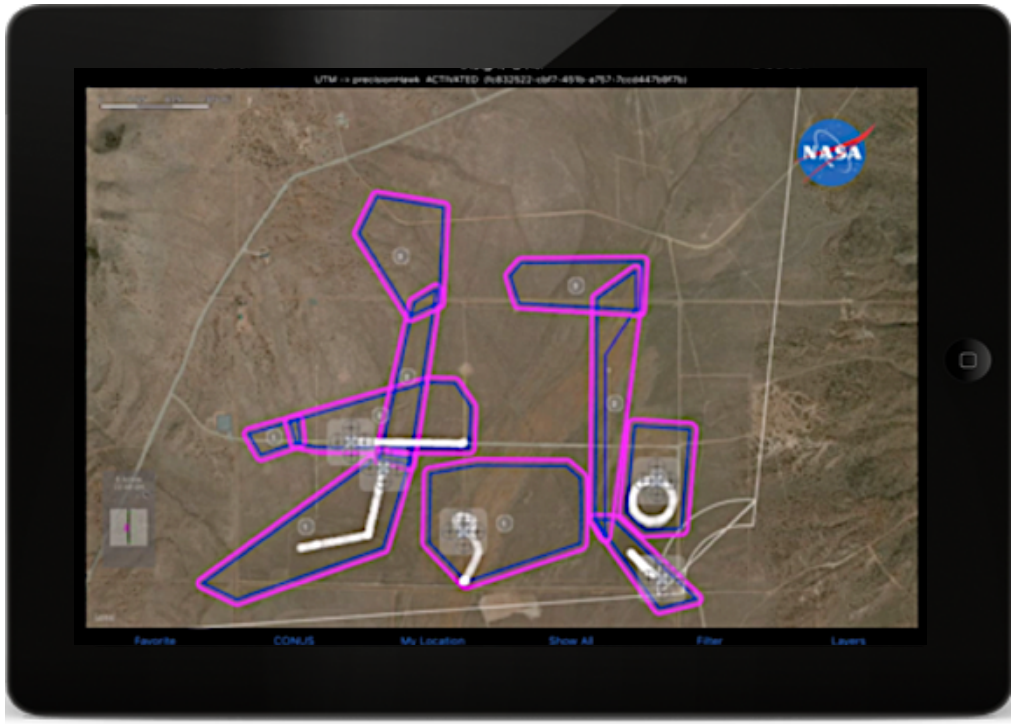
→ BVLOS to doorstep

→ Track and locate

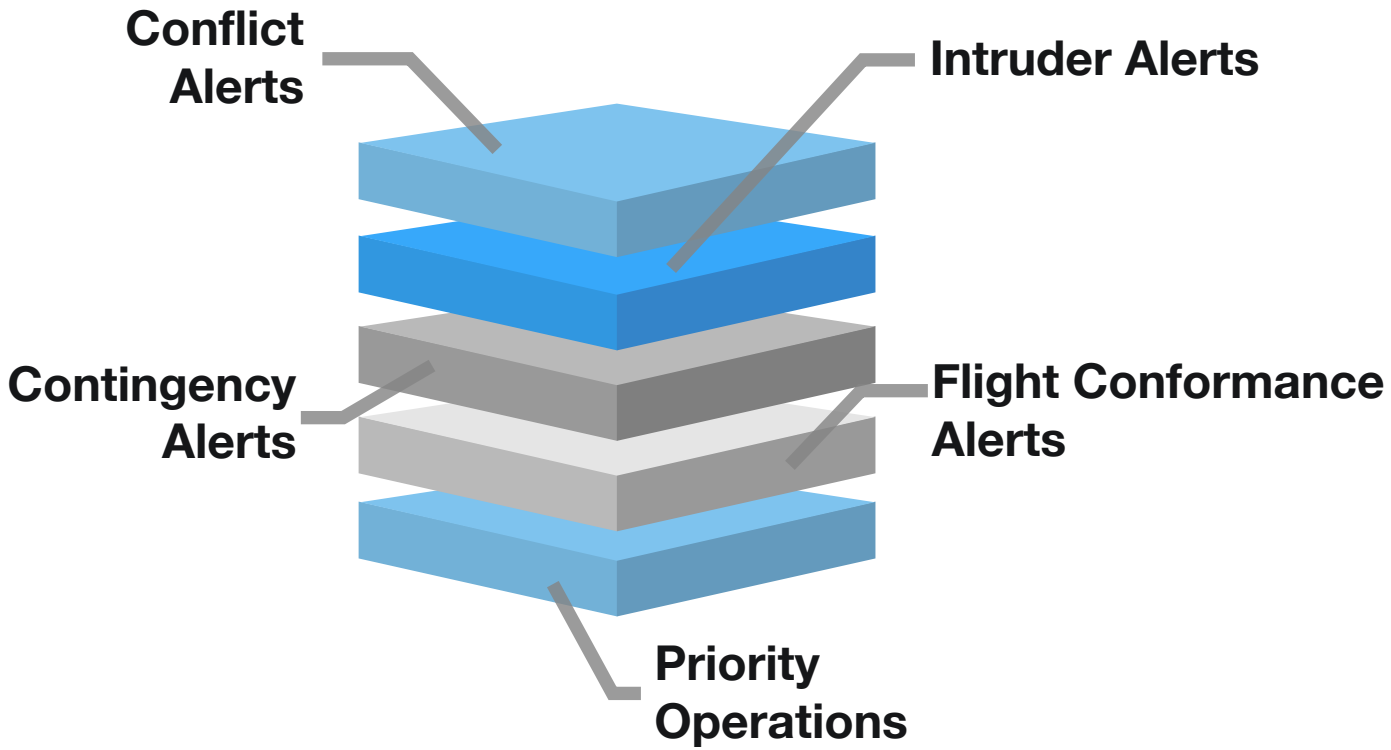
→ Avoiding dynamic obstacles

→ Large scale contingencies

TCL 2 UTM Functionality



UTM Mobile Application



Scheduling and Planning, Tracking, and Contingency Management

TCL 2 Flight Test Objective

Evaluate the feasibility of multiple BVLOS operations using a UTM research platform

Flight Test Overview

UAS Range

Elevation: 5050 feet

Desert Terrain

Missions up to 500 ft

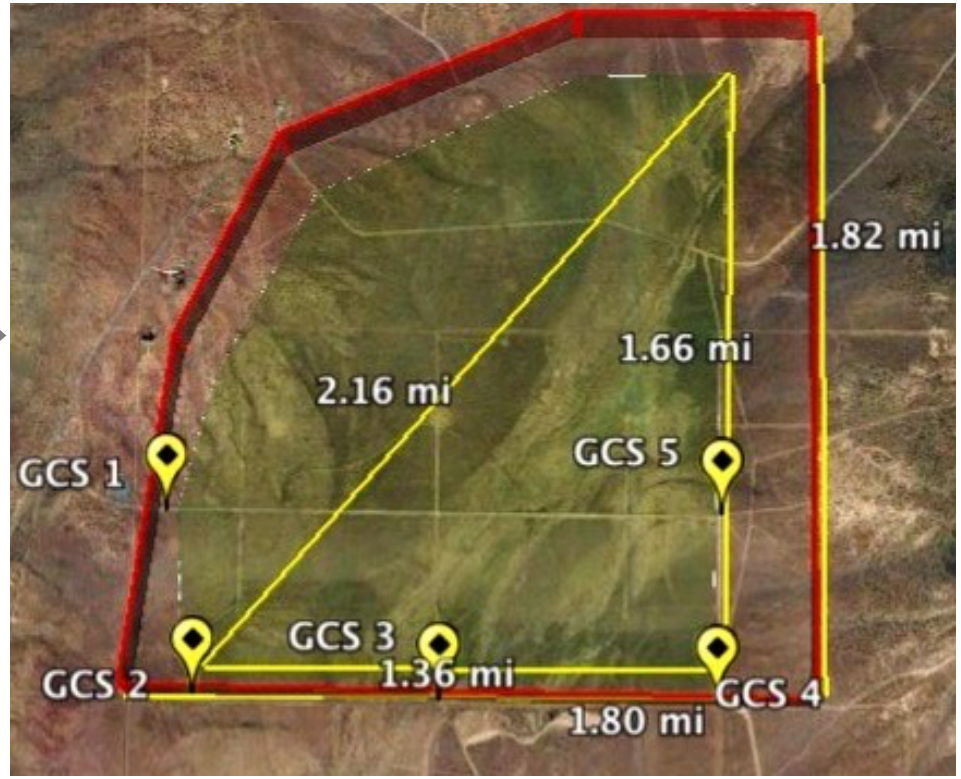
Operations at 5 Locations

SRHawk Radar

Weather Equipment

LSTAR Radar

Nevada UAS Test Range



October 2016

Flight Test Highlights

Situation Awareness Displays

Critical alerts, operational plan information and map displays

Altitude Stratified Operations

Live-Virtual Constructive Environment

BVLOS **2** + Visual Line of Sight **3** = Simultaneous Operations **5**

Flights

74

UAS Vehicles

11

Partnerships

14

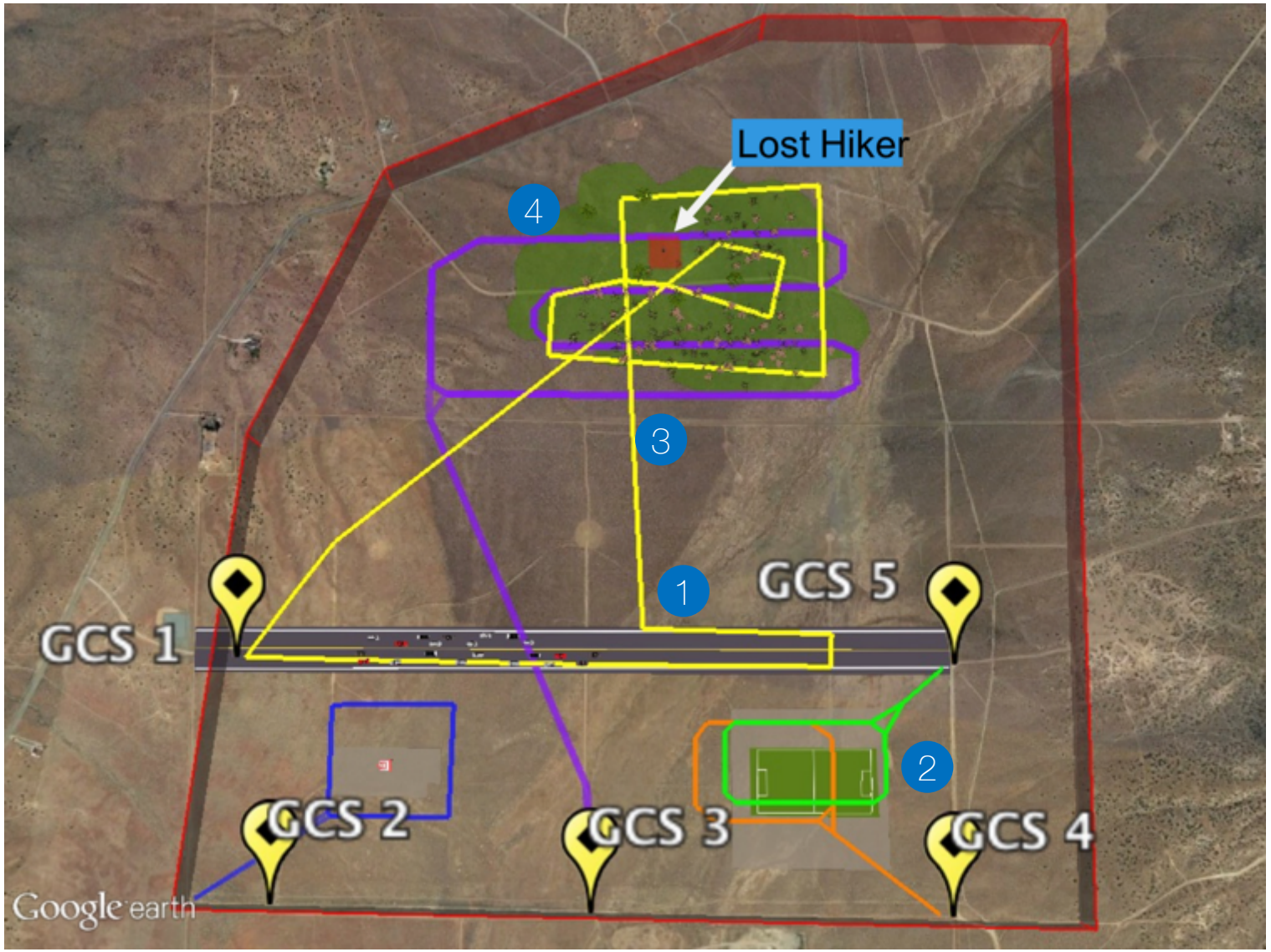
4 Scenarios

30 Minutes per scenario

Days of Flight

5

Scenario 2: Lost Hiker

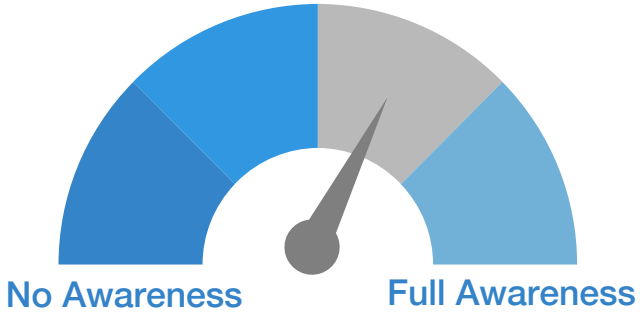


1. Dynamic Re-Routing
2. VLOS Altitude Stratification
3. Priority Operation
4. Constraint Notifications

TCL 2 Flight Test Lessons Learned

Use of the UTM Research Platform

Awareness of proximity to nearby operations



Areas for improvement:

Spectrum Usage

Contingency Management Actions

User reported information (e.g. UREP)

Integrated Airspace Display

Observations

Few flight crews had experience flying amongst other operations

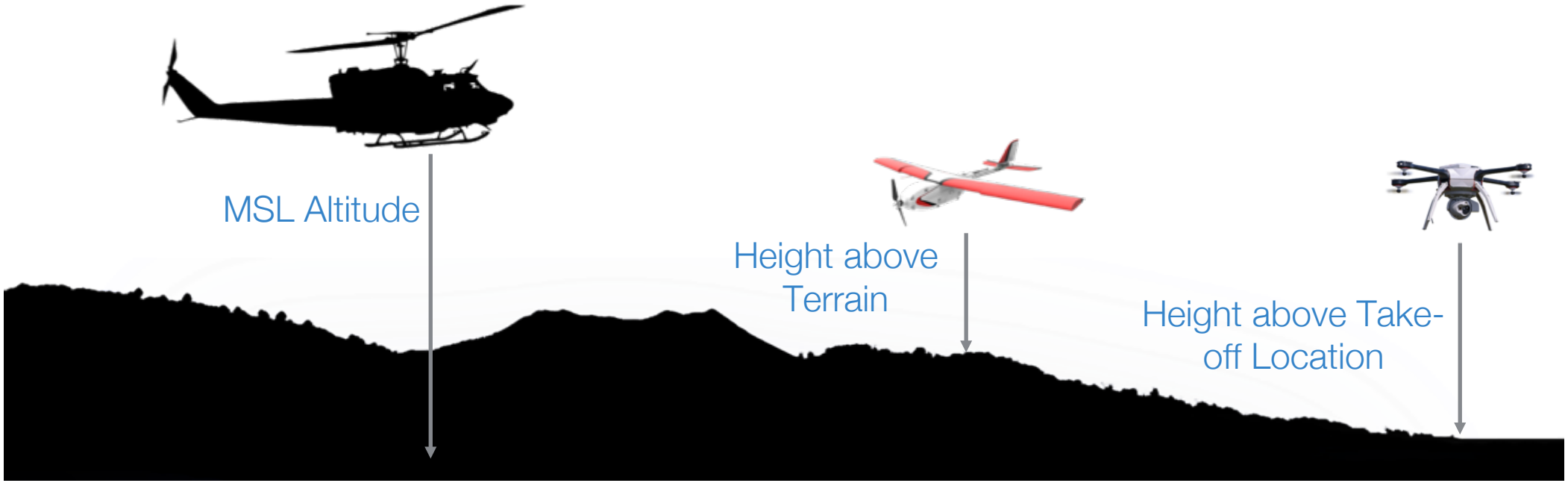
Due to differences in the equipment and practices of other operators information sharing was critical for safety

Flight crew progressed from reluctance to acceptance to endorsement of shared airspace information

UTM provided situation awareness with respect to other operations that was generally accepted by operators

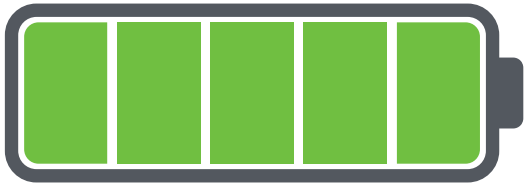
Inconsistent Altitude Reporting

Increased risk of controlled flight into terrain and airborne collision hazard



Altitude reporting should be consistent or translatable across airspace users

Weather Impact on UAS



Nominal Aircraft Endurance

Multi-Rotors: 20-40 minutes

Fixed-Wing: 45-200+ minutes

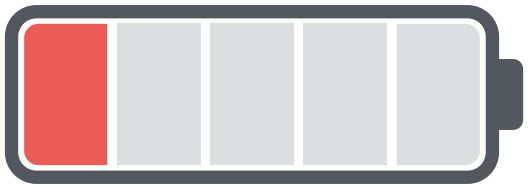
Reno-Stead Elevation: 5,050 ft

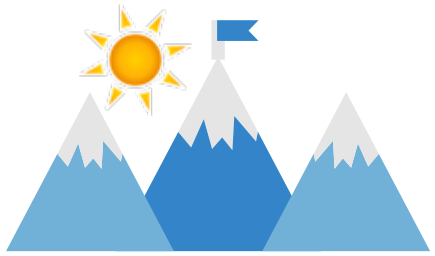
Cool Temperatures

Density Altitude: 4,000 ft

Winds: 5-35 knots

Aircraft encountered **thermals**, **microbursts** and **high winds** which resulted in **reduced endurance** and degraded flight plan conformance





Warm Temperatures

Density Altitude: 9,000+ ft

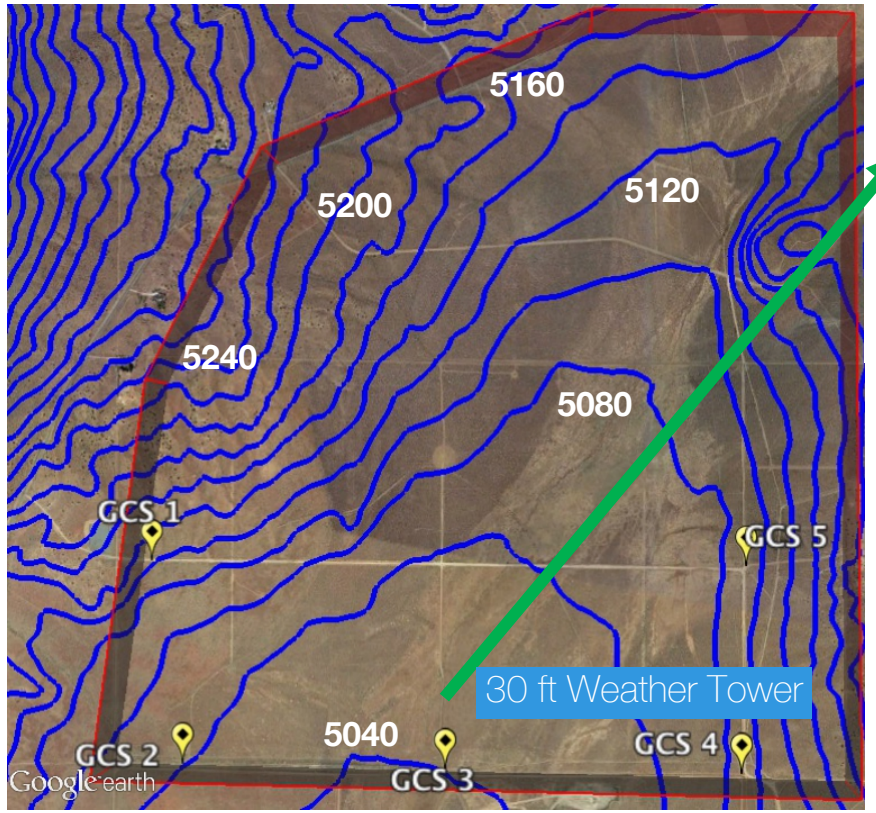
Winds: 5-15 knots

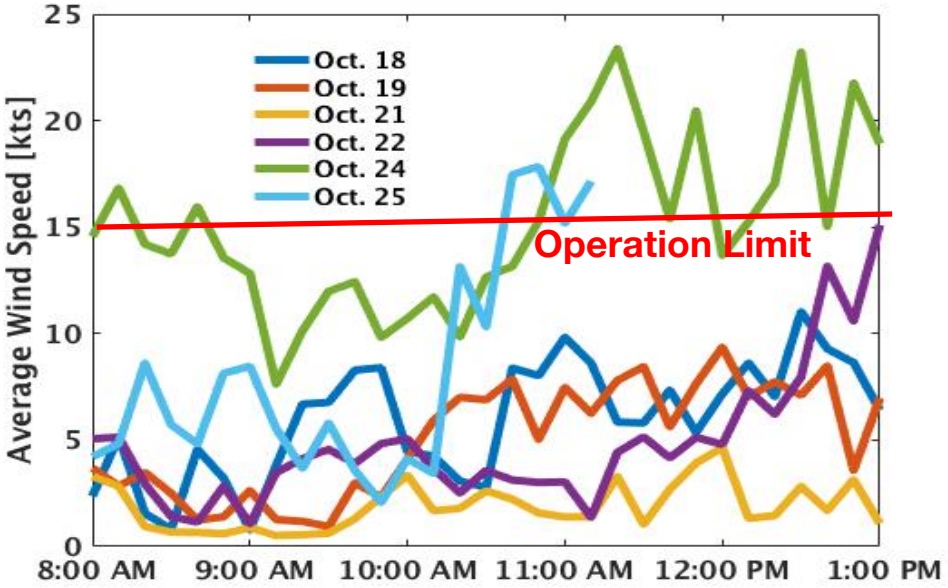
Aircraft experienced substantially **shorter endurance**

UAS should be tested and rated against different operational environments

Locality Impact on Operations

Basin and range topography yielded local micro-climates with observably different wind conditions





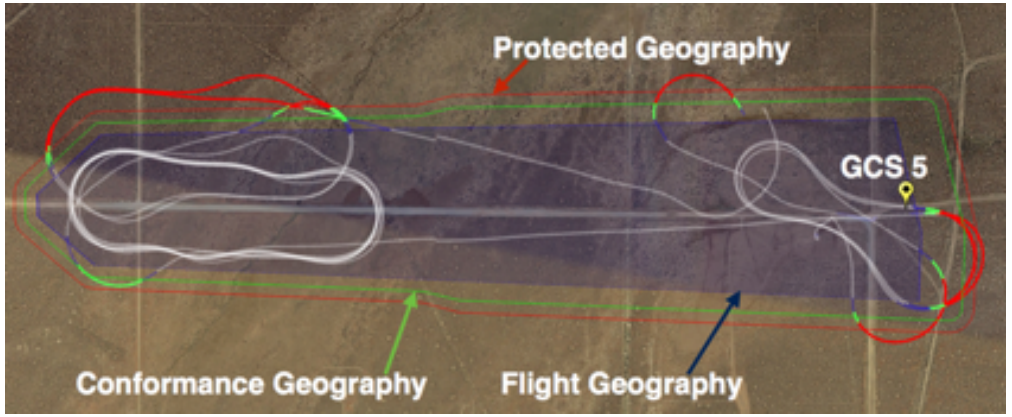
Local weather and national forecasts not indicative of observed conditions on site

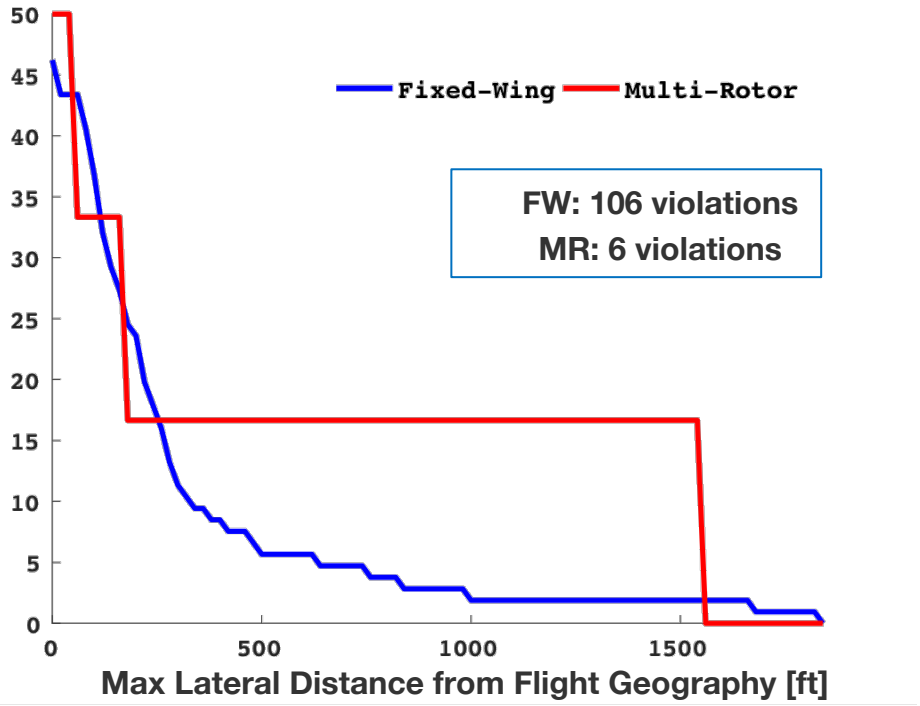
Ground reports were not indicative of conditions UAS experienced aloft

Ground reports local to GCS location was not indicative of conditions UAS experience while BVLOS

Improvements in weather products are needed to support BVLOS

Conformance to Operational Plan





35 flights conducted for data collection

46% of data collection flights experienced at least 1 instance of a flight geography violation

Common Factors leading to violation:

- ❑ Vehicle Performance
- ❑ Erroneous Waypoint / Altitude
- ❑ Erroneous Flight Geography
- ❑ Changing Launch Direction
- ❑ Pilot Error in Manual Flight Mode
- ❑ Un-reported Contingency Management Actions

Operational plans were not always consistent between UTM, GCS and UAS

Recommendations for BVLOS Operations

1. Operators should **display airspace information** and have access to other operator's operational intent and contingency actions in off-nominal conditions

2. **Altitude reporting** should be **standardized** and consistent/translatable to current airspace users

3. In the absence of acceptable weather products, **atmospheric conditions** should be **self-reported from GCS and UAS**

4. Initial BVLOS should **avoid altitude stratification**, until improved position sharing (e.g. V2V) and weather products

5. **Flight trajectories** should be **contained within geo-fence boundaries** that are shared with the UTM research platform **to support separation**

Summary

TCL 2 Demonstration successfully showed the feasibility of supporting multiple BVLOS operations in a rural environment

Areas of Improvement successfully include weather products, industry standards, and engagement from UAS manufacturers in integrating UTM functionality to support BVLOS operations.

Future work: (TCL 3 Demonstration) will evaluate the effectiveness and interoperability of technologies to support separation, communication, navigation, data-exchange, and airspace management in a complex (suburban and near airports) operational environment

Questions?